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Glenn Safety Manual – Chapter 8

Electrical Systems Safety w/Change 1 (8/16/2016)

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Change Record

Rev.	Effective Date	Expiration Date	GRC25, Change Request #	Description
D	6/9/11	6/9/2016	121	Bi-annual Review/Revision
Change 1	4/23/14	6/9/2016	N/A	Administrative change to add front cover and change history log to comply with NPR 1400.1.
E	6/24/16	6/24/2021	15-018	70E requirements and GRC expectations to meet them, (5.7) Incorporate on-site knowledge requirements, (6.1) Incorporate NPR medical requirement statement, (6.2) Allow safety program grace period to respond to code changes, (6.5) Clarification, (6.7) New NFPA 70E requirements for "Buddies", (6.9.4) Closer reference to NFPA 70E requirements, (6.10) Clarify responsibility of classification determination, (6.11.2) Clarification, (6.11.3) Clarification of DSP responsibilities, (6.13.2) Remove redundant information already covered in System Manager Operating Instructions, (6.15.1) Update training requirements to coincide with NFPA 70E and IFO Audit Findings, (6.15.2) Meet NFPA 70E three year retraining requirement, one year on AED , CPR and release of victims.
Change 1	6/24/16	6/24/2021	N/A	Administrative change to add “In addition, at GRC, whenever the Restricted Arc Flash Boundary is crossed, by reach or tool,” and added “see Appendix D.”

***Include all information for each revision. Do not remove old revision data. Add new rows to table when space runs out by pressing the tab key in the last row, far right column.*

Contents

1.0 PURPOSE 5
2.0 APPLICABILITY 5
3.0 BACKGROUND 5
4.0 POLICY 6
4.1 GRC Policy 6
4.2 Measurement and Verification 6
5.0 RESPONSIBILITIES 6
5.1 GRC Fire Protection - Authority Having Jurisdiction (AHJ) 6
5.2 Safety and Health Division (SHeD) 6
5.3 Area Safety Committees 6
5.4 Electrical Applications Safety Committee 6
5.5 Process Systems Safety Committee (PSSC) 7
5.6 Electrical Systems Managers 7
5.7 Plum Brook Station Electrical Maintenance Specialist: 7
5.8 Electrical Power Dispatcher (EPD phone # 433-3100) 7
5.9 Supervisory Personnel 7
5.10 Qualified Person 8
5.11 Certified Operator/Switchperson 8
6.0 REQUIREMENTS 8
6.1 Physical Ability Requirements *(NPR 8715.3, Section 7.4)* 8
6.2 Codes, Standards, and Instructions 8
6.2.1 National Electrical Code (NEC) (*NFPA 70)* 9
6.2.2 National Electrical Safety Code (NESC) (*IEEE C2)* 9
6.2.3 Standard for Electrical Safety in the Workplace and Arc Flash Protection (*NFPA 70E)* 9
6.2.4 Occupational Safety and Health Act (OSHA) (*29 CFR 1910 and 29 CFR 1926)* 9
6.2.5 NASA General Safety Program Requirements (*NPR 8715.3)* 9
6.2.6 Electric Power System Operating Instructions *(LVEPS–OI xx and HVEPS–OI xx)* 9
6.3 Shock 9
6.4 Electrical Isolation *(NFPA 70E, Article 130*) 10
6.5 Lockout/Tagout Procedures *(OSHA 29 CFR 1910.147 and GLM–QS–1700.1 Chapter 9)* 11
6.6 Consider All Electrical Systems Energized *(NFPA 70E, Article 120)* 11
6.7 Buddy System *(NPR 8715.3C Chapter 3.6 Electrical Safety)* 11
6.8 Work in a Confined Space (*29 CFR 1910.146, 29 CFR 1910.269, and ANSI Z117.1*) 11
6.9 General Electrical Considerations 11
6.9.1 Configuration Control (GLP-FB-8820.1) 11
6.9.2 Validation of Operating Equipment (LVEP and HVEP OIs) 12
6.9.3 Separately Derived Electric Power Systems (NFPA 70 and 70E) 12
6.9.4 Battery Systems (NEC Article 480, NFPA 1 Chapter 25) 12
6.9.5 Instrument Transformers (NEC Article 250.170) 13
6.9.6 Capacitors (NEC Article 460, NFPA 70E Article 120) 13
6.10 Hazardous (Classified) Locations *(NFPA 70, Articles 500 through 516)* 14
6.11 Special High-Voltage Electrical Safety Considerations *(HVEPS–OIs)* 14
6.11.1 High-Voltage Electrical Power System Operating Instructions *(HVEPS–OI-012)* 14
6.11.2 NASA GRC High-Voltage Designated Safety Person (DSP) (Specific HVEPS-OI-012) 14
6.11.3 Entry into Electric Supply Stations (Specific HVEPS-OI-012) 15
6.11.4 Work On or Near High-Voltage Facilities 15
6.11.5 Work in Electric Supply Stations or Near Exposed Lines or Apparatus (HVEPS-OI-012) 15
6.11.6 High-Voltage Switching (Specific HVEPS-OI-011) 16
6.11.7 Cutting High-Voltage Cables (HVEPS-OI-009) 16

6.11.8 Fuses (Removal and/or Replacement) – (NFPA 70E and GLM-QS-1700.1.8)....16
6.11.9 Lifting and Construction Equipment, Vehicles, or Personnel Near Exposed Energized Electrical Parts (HVEPS-OI-012)....17
6.12 Personal Protective Equipment (for additional information on PPE see GSM Chapter 15)....17
6.12.1 Hard Hats *(29 CFR 1910.135 and ANSI Z89.1)*....17
6.12.2 Eye Protection *(ANSI Z87.1 and ASTM F 2178)*....17
6.12.3 Safety Shoes *(ASTM F2412 and F2413)*....17
6.12.4 Rubber Insulating Gloves *(ASTM D 120 and ASTM F 496)*....17
6.12.5 Hot Sticks *(ANSI/IEEE Standard 516 and* 29 CFR 1910.269(j)*)*....17
6.12.6 Protective Clothing *(NFPA 70E)*....18
6.13 Equipment Safety Tests and Checks *(ANSI/IEEE or NETA)*....18
6.13.1 Tests To Be Performed Prior to Initial Energization....18
6.13.2 Circuit-Interrupting Devices....18
6.13.3 Protective System Checks....19
6.13.4 High-Voltage Insulation Testing....19
6.14 Experimental Equipment *(GLM–QS–1700.1)*....19
6.14.1 Safety Responsibility....19
6.14.2 Experimental, Developmental, or Flight-Level Electrical/Electronic Equipment (NFPA 70E)....19
6.14.3 Experimental Equipment Utilizing High-Voltage Capacitor Banks....20
6.15 Training (NASA General Safety Program Requirements NPR 8715.3C)....21
6.15.1 Initial Training....21
6.15.2 Employee Retraining....21
7.0 RECORDS....22
8.0 REFERENCES....22
APPENDIX A . Definitions and Acronyms....24
APPENDIX B . Examples of Signs AND LABELS....26
APPENDIX C . Correlation of Current in Amperes and Reaction with the Human Body....28
APPENDIX D. “When is the Buddy System Required During Electrical Applications”....29

Chapter 8—Electrical System Safety

Note: *The current version of this chapter is maintained and approved by the Safety and Health Division (SHeD). The last revision date of this chapter was June 2016. The current version is located within the BMS Library. Approved by Chief of Safety and Health Division.*

1.0 PURPOSE

This chapter sets forth minimum electrical safety guidelines and standards within the framework of the Glenn Research Center (GRC) safety policies and constraints. Electrical systems safety encompasses the responsibilities, regulations, and requirements that ensure a safe working environment for personnel engaged in electrical work at GRC. Minimizing hazards such as shock, arc flash, and arc blast is necessary for providing an electrically safe work environment.

2.0 APPLICABILITY

The provisions of this chapter are applicable to all NASA employees and to all other agencies, organizations, and contractor personnel, who design, construct, inspect, operate, maintain, or manage electrical systems within the confines of GRC at Lewis Field and Plum Brook Station. It is for professional designers, engineers and craftsman; it is not an instructional manual for untrained personnel nor is it a substitute for the detailed procedures judged necessary for the safe conduct of a specific electrical task.

In this chapter, all mandatory actions (i.e., requirements) are denoted by statements containing the term "shall." The terms "may" or "can" denote discretionary privilege or permission, "should" denotes a good practice and is recommended, but not required, "will" denotes expected outcome, and "are" or "is" denotes descriptive material.

3.0 BACKGROUND

The authority for the Electrical Systems Safety chapter is derived from the "NASA General Safety Program Requirements," NASA Procedural Requirement (NPR) 8715.3C, Chapter 3.6. Electricity is a common source of energy that GRC personnel are exposed to on a daily basis. It provides lighting, power to computers, and numerous manners of creature comfort. Electricity is something we have grown accustomed to using and feeling safe around, but it is that feeling of complacency that can turn electricity into one of the most dangerous and unforgiving energy sources we are exposed to. Numerous personnel injuries and fatalities have occurred through the years because unqualified persons have exposed themselves to unsafe and unguarded sources of electricity. Even trained personnel have lost their lives because of unforeseen circumstances. Electricians may think that an electrical-related accident or injury cannot happen to them, or even worse, may accept that risks are just part of the job. Accidents are not prevented based on one's knowledge of electricity; they occur because of unforeseen circumstances that place you in harm's way. Codes, standards, and regulations, listed later in this chapter, have been put in place so that trained personnel take the proper precautions to safeguard against incidents and mishaps. If a conflict in procedure arises between this chapter and local, State or Federal regulations, the most stringent requirements shall apply.

The Glenn Research Center at Lewis Field and Plum Brook Station, is varied in its electrical systems. There are high- and low-voltage, protective/security, central process, and research systems that differ in the types of work performed within and on these systems as well as hazards these systems might introduce. There are indoor, outdoor (including substations with exposed energized equipment), and underground (manholes/vaults, duct banks, etc.) components that make up these electrical systems. This document describes the different types of activities that take place on the electrical systems at GRC as well as the different voltage exposure levels to personnel. It describes the responsibilities of both personnel who are in charge of and those that work on these systems and the minimum training required.

4.0 POLICY

4.1 GRC Policy

It is GRC policy that electrical systems be designed, operated, and maintained to adequately control hazards likely to cause death or serious physical harm or severe system damage. This will be accomplished by following the Occupational Safety and Health Administration (OSHA) and industry accepted standards and policies (See Requirements section 6.0)

4.2 Measurement and Verification

Compliance with the responsibilities and requirements of this chapter are measured and verified through the use of programmatic self-assessments, regulatory and agency audits and internal field inspections and surveys.

5.0 RESPONSIBILITIES

Specific responsibilities of individuals or organizations tasked with establishing and following safety requirements for electrical systems utilized at GRC are as follows:

5.1 GRC Fire Protection - Authority Having Jurisdiction (AHJ)

The individual responsible for implementing the fire safety provisions of NPR 8715.3, "NASA General Safety Program Requirements," and with the authority for "approving/concurring in" associated installations, procedures, and equipment. The AHJ shall be permitted to render code interpretations in order to provide clarification to its requirements and approve variations/deviations to those requirements where it can be shown that alternative methods* can still maintain an effective level of safety. Existing electrical installations that do not comply with the provisions of updated/current codes shall be permitted to be continued in use unless the AHJ determines that the lack of conformity with the updated code presents an imminent danger to GRC employees or visitors. Where changes are required for correction of hazards, a reasonable amount of time shall be given for compliance, depending on the degree of the hazard.

* Technical documentation shall be submitted to the AHJ to demonstrate equivalency and that the system, method, or device is approved for the intended purpose.

5.2 Safety and Health Division (SHeD)

The SHeD, through the Operational Safety Branch, provides safety oversight and consultation that results in safe operations and practices of all programs, projects, and workers at GRC. This reduces the probability of injury to personnel and/or the prevention of damage to property. (The areas of responsibility for this Branch are described in the GRC Safety Manual). The Chief of SHeD also coordinates the appointment of Area Safety Committee members and chairs.

5.3 Area Safety Committees

The Area Safety Committees conduct third-party reviews of proposed installations, modifications, and operations in their assigned areas, to ensure that electrical systems meet minimum design, operational, and safety standards. They should also consider secondary sources of power for installations that are unable to withstand a power outage. See Glenn Safety Manual – Chapter 1A: GRC Safety Permit Program and 1B: Area Safety Committees for more information.

5.4 Electrical Applications Safety Committee

The Electrical Applications Safety Committee (EASC) reviews tasks in major electrical power systems (e.g. Substations, 10X10 and 8X6 Drives, Central Air Equipment Building). This committee is primarily responsible for high-voltage electrical power systems; however, it also, upon request, reviews new, additional, or modified electrical applications and advises applicable Safety Committees concerning electrical systems safety. The EASC issues operating safety permits for the GRC high-voltage electric power distribution systems and for the high-voltage variable frequency electric power system in Building 23. The EASC reviews and permits any construction, maintenance, or repair activity that will modify a permitted system's one-line diagram or that will require a crew to

work in the vicinity of high-voltage lines or equipment, both inside and outside of electric supply stations, on the GRC premises. The EASC also provides technical oversight of the GRC Arc Flash Protection Program which consists of:

a) Engineering services, through the Facilities Division Engineering Branch, to provide required shock and arc flash hazard analyses

b) Arc Flash Hazard Database oversight (provided by the Low and High Voltage Electrical Power System Managers as committee members)

c) Onsite safety training courses: Low Voltage Safety for Certified Electrical Operators/Switchpersons. (The onsite High Voltage Safety course will be available in the same fashion in early 2016)

d) Required Electrical Power Dispatch Training (regarding the Arc-Flash database and personnel accessing low distribution equipment).

5.5 Process Systems Safety Committee (PSSC)

The primary responsibility of the Process Systems Safety Committee is to ensure that the Central Process Systems are designed and operated safely. The PSSC conducts third-party reviews of all proposed installations, modifications, and operations that could affect systems specifically assigned to the PSSC, and ensure that all electrical systems meet the requirements of this chapter.

5.6 Electrical Systems Managers

Electrical System Managers, members of the Facilities Division (FD), ensure the system(s) and associated components are operated, maintained, and modified in a safe, effective, and efficient manner to support their intended use at the Center. They provide authoritative and expert information on technical issues, while managing the planning and prioritization of work on their assigned system. GRC System Managers also ensure either a Facilities Change Requests (GRC-29) or a GRC Safety Permit Request (GRC-919) is completed and approved prior to work being done on or near the systems they oversee.

- High-voltage Systems Manager
- Low-voltage Systems Manager
- Life Safety and Security Systems Manager
- Central Process Systems, Electrical Systems Manager (Switchgear, Motors, Drives, etc.)
- Central Process Systems, Control Systems Manager (Valve controls, Process Controls, etc.)

In some areas these Systems Managers have authored specific instructions to be adhered to when working on these systems.

5.7 Plum Brook Station Electrical Maintenance Specialist:

Works with the GRC Electrical Systems Managers for concurrence and acceptance of electrical maintenance and construction projects. Provides design and task oversight, including high voltage isolation procedures, for work on or near the high voltage distribution system at Plum Brook Station.

5.8 Electrical Power Dispatcher (EPD phone # 433-3100)

For Lewis Field only, coordinates day-to-day Central Process Systems (CPS) High Voltage activities, operates the High Voltage Distribution System and directs all electrical switching activities within these areas. Prepares the Electrical Equipment Switching Orders used to govern the isolation and restoration of power to electrical systems or equipment. Provides concurrence to the Lewis Field Designated Safety Person (DSP) whenever energized metal-enclosed electric apparatus are opened and coordinates with the Lewis Field DSP for entries and exits of personnel to electric supply stations documenting the purpose of the activities.

5.9 Supervisory Personnel

Supervisory personnel are responsible for ensuring that the requirements of this chapter (see Section 6.0) are adhered to in the design, construction, modification, operation, and maintenance of electrical systems where their

personnel may be impacted. Supervisory personnel ensure that employees are trained and meet the requirements of a "Qualified Person" (see Section 5.9) that pertain to their respective job assignments. Supervisory personnel ensure that tasks are only assigned to qualified personnel.

Supervisors maintain required records (e.g., training and licenses/certifications) to show employee is qualified and determines through regular supervision or through inspections conducted on at least an annual basis that each employee is complying with the safety-related work practices required. If the supervision or annual inspections indicate that the employee is not complying with the required safety-related work practices; the employee shall be retrained or excused from continuing further work associated with design, construction, modification, operation, and/or maintenance of electrical systems.

5.10 Qualified Person

A qualified person has skills and knowledge related to the design, modification, construction, maintenance, and operation of electrical equipment and installations and has received safety training on the hazards involved. A *qualified person* must have the ability to recognize all electrical hazards that might be associated with the work task being considered, and such persons will also be familiar with the proper use of the special precautionary techniques, personal protective equipment (PPE), including arc flash, insulating and shielding materials, and insulated tools and test equipment (see NFPA 70E, Article 110). The OSHA definition for a qualified person includes the phrase "has demonstrated skills," to meet this requirement, the supervisor or team lead shall document when and how an employee has actually demonstrated that he/she can perform the task. A person can be considered qualified with respect to certain equipment and methods but still be deemed unqualified for others. Qualified persons are responsible for adhering to the requirements set forth in this chapter in the accomplishment of their assigned tasks.

5.11 Certified Operator/Switchperson

A certified operator/switchperson is a qualified person (see previous Section 5.6) who has also received site-specific knowledge from their supervisor of both the equipment being operated and the system(s) it may affect and has completed SATERN Course GRC-4R1690: GRC Low Voltage Safety for Certified Electrical Operators/Switchpersons training. It is also an individual who has received instruction on lockout and/or tagout through the GRC Lockout/Tagout Program.

6.0 REQUIREMENTS

All personnel performing work on the various electrical systems at GRC shall have a working knowledge of the following documents, procedures, and policies and shall comply with the requirements therein. If a conflict in procedure or policy arises between this chapter and local, State or Federal regulations, the most stringent requirements shall apply. Organizations involved in these tasks shall, upon request, provide support information and/or documentation (Including training records if not available through SATERN) to the Operational Safety Branch to show compliance with these requirements. Failure to observe the requirements of this section shall be reason for disciplinary action.

6.1 Physical Ability Requirements *(NPR 8715.3, Section 7.4)*

Supervisors or Team leads shall ensure that personnel who perform or control hazardous operations (working on or near energized equipment) have the physical ability (if specified in the job classification) to do the job safely.

6.2 Codes, Standards, and Instructions

The following codes, standards, and instructions relate to the safe design, installation, construction, operation, and maintenance of electric power systems at GRC. The latest versions of these publications/documents shall be adhered to.

NOTE: Upon issuance (and Agency acceptance) of revised codes, standards, and instructions, a six (6) month compliance "grace period" will be given to allow organizations to meet the new requirements unless the SHeD and/or AHJ determines that the lack of conformity with these changes present an imminent danger to employees.

6.2.1 National Electrical Code (NEC) (*NFPA 70)*

The NEC (NFPA 70) covers electrical conductors and equipment installed within or on public and private buildings and other premises. This code is the primary code covering design and installation of electrical power systems. This document also covers electrical requirements for Hazardous Classified locations where there is a potential for fire and explosion because of flammable gases or vapors, flammable liquids, combustible dust, or ignitable fibers or flyings.

6.2.2 National Electrical Safety Code (NESC) (*IEEE C2)*

The NESC (Institute of Electrical and Electronics Engineers (IEEE) and American National Standards Institute (ANSI) C2) provides rules for the practical safeguarding of persons during the installation, operation, or maintenance of electric supply and communication lines. (*Substations facilities & distribution systems, applies to utilities and similar systems associated with multi-building industrial complexes).*

6.2.3 Standard for Electrical Safety in the Workplace and Arc Flash Protection (*NFPA 70E)*

This standard addresses electrical safety requirements for employee workplaces that are necessary for the practical safeguarding of employees during activities downstream of the electrical service point such as the installation, operation, maintenance, and demolition of electric conductors, electric equipment, signaling and communications conductors and equipment, and raceways. This standard also sets the requirements for the GRC Arc Flash Protection Program. Appendix D, shows an example of an arc flash warning label.

6.2.4 Occupational Safety and Health Act (OSHA) (*29 CFR 1910 and 29 CFR 1926)*

OSHA (Public Law 91–596) covers conditions, practices, and operations to ensure safe and healthful workplaces.

6.2.5 NASA General Safety Program Requirements (*NPR 8715.3)*

This document is the central Agency document containing procedures and guidelines that define the NASA Safety Program.

6.2.6 Electric Power System Operating Instructions *(LVEPS–OI xx and HVEPS–OI xx)*

The GRC Low-Voltage Electrical Power System (LVEPS) and High-Voltage Electrical Power System (HVEPS) managers periodically issue numbered operating instructions applicable to their respective systems. These are on-site instructions to be followed when working on a GRC Facility. They can be attained through the FD website.

6.3 Shock

6.3.1 Electrical (NFPA70E)

Employees exposed to shock hazards shall be trained, per NFPA 70E, in methods of release of victims from contact with exposed energized electrical conductors or circuit parts. Employees shall be regularly instructed (biennially) in methods of first aid and emergency procedures, such as approved methods of resuscitation (cardiopulmonary resuscitation (CPR), automated external defibrillator (AED), etc.). See Appendix C noting the correlation of Current in Amperes and the Reaction of the Human Body to the electric current.

6.3.2 Electrostatic (NPR 8715.3C para 3.6.1i)

The familiar phenomenon of a static shock–more specifically, an electrostatic discharge (Spark)–is caused by electrons flowing between objects at different electric potentials coming close to or in contact with one another.

Sparks are responsible for the majority of industrial fires and explosions where static electricity is involved. Many semiconductor devices used in electronics are very sensitive to the presence of static electricity and can be damaged by a static discharge. Personnel working with this type of equipment are required to be knowledgeable of this phenomenon and the precautions to be taken. Good grounding of all parts of the equipment and precautions against charge buildups on equipment and personnel through common conductive paths (i.e. conductive wristbands, tables, and floors) shall be used as prevention measures. See Reference *ESD TR20.20-2008 - Handbook for the Development of an Electrostatic Discharge Control Program for the Protection of Electronic Parts, Assemblies and Equipment.*

6.4 Electrical Isolation *(NFPA 70E, Article 130)*

As a rule, GRC does not allow work on energized electrical systems. Exceptions are provided for specific tasks allowed in NFPA 70E, Article 130. A GRC System Manager and/or GRC Safety Committee Chair may concur with other exceptions to this policy after careful review of the situation and hazards involved. Such decisions shall be documented using an Energized Electrical Work Permit (GRC780). After permission is granted to work on energized equipment only tools designed and rated for the voltage level of the system voltage shall be used. Only devices designed for voltage testing and rated for the nominal voltage of the circuit under test shall be used to make voltage checks. Each test voltage indicator shall be verified before and after use by using the hot-dead-hot technique. Only qualified persons who have been trained to work safely with test instruments and equipment on energized circuits shall be permitted to perform such tests.

Whenever energized metal-enclosed electric supply apparatus (including high- or low-voltage, metal-enclosed switchgear, unit substations, panel boards, and switchboards that normally isolate the public from electrically energized components) are opened, special precautions shall be taken. Energized metal-enclosed electric supply apparatus shall not be opened without concurrence of the Electric Power Dispatcher at the GRC Lewis Field, or the Electrical Maintenance Specialist at the GRC Plum Brook Station.

NOTE: Removal or replacement of bolted covers larger than 4’ diagonally on panels greater than 240V (to expose bare, energized electrical conductors or parts) with a HRC or PPE category of 1 or greater shall require the panel to be de-energized or submittal and approval of an Energized Electrical Work Permit. Once removed the panel may be re-energized until time to replace the cover. This requirement is to prevent accidental contact with energized parts while removing large and cumbersome conductive covers.

For a low-voltage power apparatus, rated insulated barriers shall be placed over the exposed energized parts, warning sign(s) shall be placed, and flash protection and physical approach boundaries shall be established. If the qualified person who opened the electrical supply apparatus must leave the area, the opened facilities shall be closed and secured. For a high-voltage apparatus, flash protection and physical approach boundaries shall be established, suitable high-voltage warning signage shall be placed and a NASA GRC high-voltage Designated Safety Person (DSP) shall be in attendance (see Section 6.11). No personnel shall be permitted to enter the work area without permission of the NASA GRC high-voltage DSP. The NASA GRC high-voltage DSP shall confirm that all personnel within the work area are aware of exposed electrically energized components. When the NASA GRC high-voltage DSP leaves the area, either a new GRC high-voltage DSP shall be designated and in attendance or the opened facilities shall be closed and secured (i.e., locked if possible).

To isolate a low-voltage electrical power apparatus, GRC requires a minimum of one electrical open. To isolate high-voltage apparatus, GRC requires two opens, when that cannot be achieved, one electrical open with grounds in place shall suffice. These grounds do not replace the need for working (safety) grounds being placed by the personnel performing the high-voltage tasks. When isolation or lockout/tagout causes a disruption in service an Area Clearance form (NASA GRC978) is required prior to beginning work. The Area Clearance Procedure, GLP-QS-1100.2 can be found through the GRC WING Page Transport box.

An Electrical Equipment Switching Order (when a written lockout/tagout plan is required) shall govern all scheduled switching, isolation, locking out, tagging out, or grounding of any part of the GRC electrical power systems. Particular effort shall be made to ensure that all potential power sources, including potential transformers (PTs), are disconnected to preclude back feed of power to the isolated site. An Electrical Equipment Switching Order shall govern the restoration of power to isolated systems or equipment. Such orders shall be prepared by the Electric Power Dispatcher at the GRC Lewis Field, or by the responsible engineer at Plum Brook Station. All switching procedures shall comply with the National Electrical Safety Code, ANSI C–2, Part 4.

Each switch person shall be a Qualified Operator for the specific electrical power system and equipment involved, shall have a copy of the written switching procedure, and shall initial the written switching procedure attesting to completion of each step of the procedure as it is completed.

6.5 Lockout/Tagout Procedures *(OSHA 29 CFR 1910.147 and GLM–QS–1700.1 Chapter 9)*

Lockout/tagout procedures shall be followed whenever work is being performed on a system or piece of equipment where isolation and/or control of hazardous energy is required to prevent injury to personnel. Refer to Glenn Safety Manual, Chapter 9 for details on Lockout/Tagout procedures.

6.6 Consider All Electrical Systems Energized *(NFPA 70E, Article 120)*

All electrical systems and equipment shall be considered energized until verified to be de-energized and grounded (as required) prior to beginning hands-on work. Verification that an electrical apparatus is de-energized shall be made using a suitable voltage detector by using the hot-dead-hot technique. Subsequent verification may be made by observing the open position of isolating breakers, switches, and links in sectionalizing boxes, or by observing the personnel safety grounds installed at the worksite.

Where new work is incrementally energized during the checkout process or is energized at any time during the construction phase prior to placing the new system into service, temporary warning tags shall be placed on the energized new work.

A suitable tag to use is a "CAUTION DO NOT OPERATE," NASA GRC946 tag, Stock Number 7530–01–LNO–1281, stating in the remarks section why the tag is being placed. This tag merely indicates the status the system has been left in or system/equipment configuration.

6.7 Buddy System *(NPR 8715.3C Chapter 3.6 Electrical Safety)*

Supervisors shall ensure that no person works alone with high voltage electricity. In addition, at GRC, whenever the Restricted Arc Flash Boundary is crossed, by reach or tool, and one person ("THE BUDDY"), trained to recognize electrical hazards, is delegated to watch the movements of other personnel working with electrical equipment, energized at 50 V or more, to warn them if they get dangerously close to live conductors or perform unsafe acts and to assist in the event of a mishap (see Appendix D).

NOTE: NFPA 70E requires that employees exposed to shock hazards and those employees responsible for taking action in case of emergency (The "BUDDY") shall be trained annually in methods of release of victims from contact with exposed energized electrical conductors or circuit parts. These employees shall also receive annual instruction in methods of first aid and emergency procedures, such as approved methods of resuscitation and automatic external defibrillator (AED) use. GRC Course GRC-111-15: SAFE RELEASE OF AN ELECTRICAL SHOCK VICTIM is available through SATERN to meet this training requirement.

6.8 Work in a Confined Space (*29 CFR 1910.146, 29 CFR 1910.269, and ANSI Z117.1*)

Many electrical systems are contained within confined spaces. Entry into confined spaces is governed by procedures detailed in the Glenn Safety Manual, Chapter 16. In addition, if high-voltage cables or equipment are contained within the space, the High-Voltage Electrical Power Systems Manager or Chair of the Electrical Applications Safety Committee (EASC) shall be notified. A Safety Permit Request (NASA GRC923) may need to be submitted to the EASC if work is to be performed within major electrical power systems (e.g. Substations, 10X10 and 8X6 Drives, Central Air Equipment Building). Specific requirements for entering confined spaces containing high-voltage electric supply equipment or cables are described in HVEPS–OI–004.

6.9 General Electrical Considerations

This section presents general GRC policies for work done on or near electrical power systems. The appropriate Systems Manager shall approve exceptions to these policies.

6.9.1 Configuration Control (GLP-FB-8820.1)

The GRC has placed certain electrical power systems, including their control and protective systems, under configuration control, GLP-FB-8820.1, Configuration Management of Facilities and Institutional Systems. Systems under configuration control are:

a. High-voltage electric power distribution systems (See Section 6.11, Special High-voltage Electrical Safety Considerations)

b. Low-voltage electric power distributions systems

c. Variable Frequency Power System (Building 23)

d. Electrical power systems associated with major research facilities

When working on these systems where a change to one-lines, legends, names or functions occur, submittal and approval of a Facilities Change Request is required, Form GRC29.

6.9.2 Validation of Operating Equipment (LVEP and HVEP OIs)

New or repaired electrical equipment, where the repair involved the insulation system, and equipment that has not been energized for an extended period of time (3 months for outdoor/6 months for indoor equipment) shall be tested to ensure that the equipment's dielectric strength is at a safe level before energizing. The appropriate Systems Manager should be consulted for specific testing requirements for a particular piece of equipment.

In general, power system equipment shall be tested using a direct current (dc) "megger" appropriate to the circuit voltage. Instructions provided by the megger manufacturer, including calculations to correct readings for temperature and humidity conditions, shall be followed in the use of the megger instrument.

Copies of all validation test reports shall be submitted to the appropriate power Systems Manager for review and concurrence. Energizing of new or repaired power system equipment requires approval, via email, by the Electrical Systems Manager. The Electrical Power Dispatch Office shall receive an email authorization from the appropriate Systems Manager prior to energizing new or repaired electrical equipment.

6.9.3 Separately Derived Electric Power Systems (NFPA 70 and 70E)

Separately derived electric power systems whether derived from generators, transformers, converter windings, photovoltaics, or batteries, present unusual safety considerations. Design, installation, operation, and maintenance of such systems shall conform to the "National Electrical Code" (NFPA 70) and to the "Standard for Electrical Safety in the Workplace" (NFPA 70E). Designs for such systems shall be reviewed and approved by the appropriate GRC Electrical Systems Manager. The Systems Manager approving the installation of a separately derived system shall maintain a file that includes copies of the design documents and calculations reviewed, minutes of any meetings related to the review/approval process, and the approval memo, e-mail, or safety permit. This file shall be maintained for the life of the separately derived system include changes to the separately derived system that have been reviewed, approved, and documented

6.9.4 Battery Systems (NEC Article 480, NFPA 1 Chapter 25)

Design and installation of all stationary installations of storage batteries is governed by NEC Article 480. Ventilation systems (see NFPA 1, Chapter 52), forced or natural, shall be designed and maintained to prevent buildup of explosive mixtures. The employee needs to understand that battery charging might generate significant quantities of hydrogen and other flammable gases. This maintenance shall include a functional test of any associated detection and alarm systems, see NFPA 70E Article 240.

When selecting work practices and PPE, the employee must consider exposure to these hazards as well.

The nature of batteries is such that they cannot be shut off, therefore special care and handling is required to perform installation, maintenance, or testing. Working with batteries exposes an employee to both potential shock and arc flash hazards. In addition to the electrical hazards, batteries expose an employee to hazards associated with the chemical electrolyte used in the battery. When selecting work practices and PPE, the employee must be trained to consider exposure to these hazards as well, see NFPA 70E Article 320.

NFPA 70E Article 320.1 covers electrical safety requirements for the practical safeguarding of employees while working with exposed stationary storage batteries that exceed 50 volts, nominal.

NFPA 70E Article 320.3 covers particular safety procedures to be adhered to, such as;

- Battery Room or Enclosure Requirements (Personnel Access to Energized Batteries, Illumination).
- Apparel (Personnel shall not wear conductive objects such as jewelry while working on a battery system).

- Abnormal Battery Conditions (i.e. alarms for early warning).
- Warning Signs (warning signs or labels shall be posted in appropriate locations).
- Batteries with Liquid Electrolyte.
    - Goggles and face shield appropriate for the electrical hazard and the chemical hazard
    - Gloves and aprons appropriate for the chemical and electrical hazards
    - Portable or stationary water facilities for quick drenching or flushing of the eyes and body
- Batteries with Solid or Immobilized Electrolyte (non-spillable).
    - Goggles or face shield appropriate for the electrical hazard
    - Gloves appropriate for the electrical and chemical hazards
    - Protective clothing appropriate for electrical hazard

Additional precautions for battery work include:

- Facilities shall be provided for flushing and neutralizing spilled electrolyte, OSHA 1926.441(a)(7). If battery electrolyte should come into contact with skin or clothing, immediately treat it with water or a weak neutralizing solution. Electrolyte in the eyes, however, is a very dangerous situation; immediately flush the eyes with profuse amounts of water then seek medical attention.
- Refer to LVEPS–OI–008, "Work On or Near Low Voltage Electrical Systems" for other possible precautions and considerations.

6.9.5 Instrument Transformers (NEC Article 250.170)

The following precautions shall be observed in handling instrument transformers.

a. Current transformer cases and secondaries shall be grounded. Where more than one set of current transformers are connected electrically, a ground point shall be selected that provides grounding for the network.

b. Secondaries of current transformers (CTs) shall never be opened while the primary circuit is energized. If current is passing through the primary of a CT, and the secondary circuit is not connected to the current coil, a very high and dangerous voltage will be present. The CT becomes a voltage step-up transformer under this condition. Therefore, it is important to always short the X1 and X2 terminals to each other before breaking the circuit. Shorting bars or shorting terminal strips are permanently installed on most CTs or CT circuits for this purpose.

c. Always ensure potential transformers (PTs) fuse are removed from circuits to be worked on.

d. The case and one wire of the low-voltage side of potential transformers shall always be grounded before energizing the transformer.

6.9.6 Capacitors (NEC Article 460, NFPA 70E Article 120)

Design and installation of all capacitors, except surge capacitors or capacitors furnished as a component part of other apparatus are governed by NEC Article 460. Before employees work on capacitors, the capacitors shall be disconnected from the energizing source, residual charge shall be bled off through a suitable current limiting resister, and the capacitor(s) shall be grounded. Capacitors shall be isolated and the absence of the stored voltage verified utilizing proper PPE as required in NFPA 70E Article 120. Since capacitor units may be connected in series-parallel configurations, after residual charge is bled off, each unit shall be shorted between all insulated terminals and the capacitor tank before handling. Racks for capacitors shall be grounded. Any internal resistor shall not be depended upon to discharge capacitors. Also, see Section 6.13 for special requirements for high-voltage capacitor banks used as part of experimental equipment.

6.10 Hazardous (Classified) Locations *(NFPA 70, Articles 500 through 516)*

Many facilities and test rigs employing or storing flammable gases or vapors, flammable liquids, combustible dust, or ignitable fibers or flyings exist at the GRC Lewis Field and Plum Brook Station. These areas are classified as hazardous locations and require proper design to address these hazard classification(s) and approval of those classification(s) from the Operational Safety Branch, Area Safety Committee, or appropriate Approving Authority before construction and/or becoming operational. Guidance for classifying areas is contained in various NFPA publications. Requirements for electrical and electronic equipment and wiring for all voltages in such classified locations is covered in the NEC, NFPA 70 Articles 500 through 516.

> The following is an excerpt taken from the NFPA 70E Handbook; "The NEC does not classify specific Class I, II, and III locations. NFPA technical committees and the American Petroleum Institute (API), among other organizations with experience and expertise in working with flammable liquids, gases, vapors, dusts, fibers and flyings inherent to a process or present under abnormal conditions of operation, determine the parameters, distances, and degrees of hazard associated with classified locations."

Once the determination of the locations hazardous classification has been made the design and resultant installation shall be in compliance with all NEC requirements. All hazardous (classified) locations shall have suitable and prominent warning signs clearly posted to identify that the area is a classified location, what the area classification is, and the organization responsible for the area. Signs shall be framed and securely mounted. Signs shall be 8.5 by 11 in. or larger.

NOTE: NEC paragraph 500.5(A) FPN reminds us that "Through the exercise of ingenuity in the layout of electrical installations for hazardous (classified) locations, it is frequently possible to locate much of the equipment in a reduced level of classification or in an unclassified location and, thus, to reduce the amount of special equipment required." Responsible personnel shall involve the Operational Safety Branch early in evaluations of use of hazardous materials and the need for classified electrical equipment during design and prior to the installation/operation of such equipment.

No construction or change to operating procedures shall be allowed within a hazardous (classified) area without a review conducted by the applicable Safety Committee that documents the rationale leading to approval of the construction or change to operating procedures.

The organizational element responsible for a hazardous (classified) area shall maintain a file relating to the area. Such files shall contain the document(s) identifying area classifications. Supporting documents such as calculations, preliminary and final hazard analyses, and related meeting minutes shall be included in the file.

6.11 Special High-Voltage Electrical Safety Considerations *(HVEPS–OIs)*

6.11.1 High-Voltage Electrical Power System Operating Instructions *(HVEPS–OI-012)*

These instructions as mentioned previously in section 6.2.6 are authored by the High-Voltage Electrical Power Systems Manager, the following is a brief synopsis of the more detailed OI's.

6.11.2 NASA GRC High-Voltage Designated Safety Person (DSP) (Specific HVEPS-OI-012)

A GRC High Voltage Designated Safety Person (DSP) is required for all electrical or non-electrical work tasks performed on institutional high voltage (greater than 600V) electrical equipment throughout the high voltage electric power system. A DSP may also be required when working near high voltage electrical equipment. The determination of whether a DSP is required when working near high voltage electrical equipment will be based on the nature of the task being performed and the area in which that activity occurs. This requirement will be reflected on the Electrical Applications Safety Permit for any construction/maintenance activities and in the operating safety permit for the system/equipment (For example: all activities within fenced outdoor substations having air insulated exposed bus requires the presence of a DSP).

Examples of work requiring a DSP:

- Switching, isolating, tagging, locking out and/or grounding of high voltage electrical equipment.

- Entering or working in confined spaces, such as: power manholes, electric cable tunnels, electric cable rooms, transformer vaults, etc.
- Opening of metal enclosed high voltage switchgear including low voltage compartments of power transformers.

The specific duties and requirements for the DSP in the high-voltage electrical power systems are described in HVEPS–OI–012.

A DSP MUST BE PRESENT BEFORE ANY ACCESS COVERS, HATCHES, OR DOORS TO HIGH-VOLTAGE AREAS OR EQUIPMENT ARE OPENED OR REMOVED.

It is the responsibility of project management and supervisory personnel to ensure this requirement is adhered to. Failure to meet this requirement will result in a work stoppage and possible barring of re-entry.

6.11.3 Entry into Electric Supply Stations (Specific HVEPS-OI-012)

Entry into electric supply stations by other than the authorized maintenance personnel (as posted on signs at each entry, see Appendix B) requires the presence of a DSP. Such entries shall be coordinated through the Electric Power Dispatcher at Lewis Field and through the Plum Brook Management Office at Plum Brook Station. The DSP shall notify the Electric Power Dispatcher upon entering and leaving the station. Such notification shall include the purpose of the activity.

6.11.4 Work On or Near High-Voltage Facilities

6.11.4.1 On High-Voltage Facilities (Specific HVEPS-OI-011)

The general requirement for working on high-voltage electric supply equipment or lines shall be to provide two open breaks in series on all electrical phases between the work site and each energy source, including back feeds, and one open break between the work site and potential transformers. Visible protective safety grounds shall be provided either on both sides of the work site or at the work site.

This general requirement, called two opens, shall be the Center's objective and shall be met in the majority of Electrical Equipment Switching Orders to isolate high-voltage electric supply equipment or lines. The Electrical Power Dispatcher shall approve exceptions to this general requirement.

When more than one work site exists on isolated high-voltage electric supply equipment or lines, such as along overhead 7200- or 34 500-V distribution lines, visible protective safety grounds shall be provided at both ends of the distribution line and at each work site.

6.11.4.2 Near High-Voltage Facilities (HVEPS-OI-011 and 012)

When work is performed near high-voltage electric supply equipment or lines utilizing air-insulated configurations, such high-voltage supply equipment or lines shall be isolated and grounded or the high-voltage facilities shall have suitable guards installed which preclude encroachment into minimum safe working clearances from the energized facilities.

When work is performed near insulated high-voltage electrical cables and associated cable apparatus, cables and associated cable apparatus are not required to be de-energized. For such cases when cables or cable apparatus are requested to be de-energized, only one electrical break is required. Utilization of protective safety grounds is optional.

> ***Note:*** *Specific electrical isolation and grounding requirements for the high-voltage power systems are presented in HVEPS–OI–011, "Work On or Near High-Voltage Electrical Systems." Minimum safe working distances from air-insulated high-voltage apparatus are shown in HVEPS–OI–012.*

6.11.5 Work in Electric Supply Stations or Near Exposed Lines or Apparatus (HVEPS-OI-012)

For all work within energized high-voltage electric supply stations or in the vicinity of exposed energized high-voltage lines or apparatus:

a. Each contractor shall abide by all applicable OSHA, NEC, NESC, and GRC safety rules and regulations. GRC Safety Documents that exist and receive authorization through the Glenn Safety Manual are incorporated into the contractor's contract by reference, and as such, have the same force and effect as if they were given in full text. The full text of the GRC safety documents shall be provided to the contractor upon the contractor's request of the Contracting Officer.

b. Each contractor shall appoint an individual (employee in charge) to be responsible for the electrical safety of each of the contractor work teams. Before starting the work, the contractor shall provide a document to the Government establishing that the employee in charge is qualified and knowledgeable in all required safety regulations. This individual shall verify that each work area, and a safe zone beyond the work area, has been de-energized and made safe (properly isolated and grounded) before permitting a team to work in the energized electric supply station.

Note: *This requirement is not to be confused with the GRC high-voltage DSP.*

c. Each contractor shall abide by all barriers and rope guards, placed by the GRC DSP, to clearly define the safe work zone and to prevent the workers from inadvertently moving out of the safe work area. Work area separation from exposed energized lines and apparatus is established in HVEPS–OI–012.

6.11.6 High-Voltage Switching (Specific HVEPS-OI-011)

Only personnel who are listed on an approved Qualified Operator's List (GRC580) as qualified for the specific circuits or equipment shall perform high-voltage switching.

The following precautions must be observed:

Disconnecting poles (hot sticks) and rubber gloves shall be used when operating high-voltage, hook-stick-operated disconnecting switches having open circuit voltages. The following table lists the minimum pole length for various voltages:

TABLE 6.1.—MINIMUM HOT STICK LENGTHS (ft.)

Voltage	Minimum length of hot stick,
601 to 7500	4
7501 to 50 000	8
50 001 to 73 000	12
73 001 to 138 000	16

a. Rubber gloves with leather protectors shall be worn when operating any manually operated, mechanically connected, remotely controlled air break switch where the voltage exceeds 600 V. No work shall be done on circuits or equipment isolated from power sources by oil switches alone.

b. A switch person operating any switch used for maintenance or for isolation of circuits above 600 V shall be accompanied by a DSP who shall stand at a safe distance and be prepared to take any necessary steps in event of an emergency.

6.11.7 Cutting High-Voltage Cables (HVEPS-OI-009)

Cutting high-voltage cables when neither end of the cable is visible from the location of the cut presents unique safety considerations. The procedure to identify and cut high-voltage electric cables is governed by HVEPS–OI–009.

6.11.8 Fuses (Removal and/or Replacement) – (NFPA 70E and GLM-QS-1700.1.8)

Removal/Replacement of fuses may be accomplished once the fuse is disconnected from all sources of electrical energy. Removal/replacement of fuses from an energized circuit shall require an Energized Electrical Work Permit (Form GRC780). Fuses shall not be removed on energized circuits above 34. 5kV. **Fuses are not to be replaced under load**.

When removing or replacing fuses on unloaded energized circuits insulated fuse extractors and NFPA 70E Hazard/Risk Categories (HRC) with the associated required PPE shall be used:

Exception: *An Energized Electrical Work Permit is not required for Control power, Instrumentation, and Potential Transformer (PT) secondary fuses being removed or replaced with the circuit energized, as long as the transformer the systems are connected to is rated less than 240V and 125 kVA or smaller.*

6.11.9 Lifting and Construction Equipment, Vehicles, or Personnel Near Exposed Energized Electrical Parts (HVEPS-OI-012)

- Personnel working near and/or using hoisting, lifting, or other construction equipment or vehicles near air-insulated energized electrical lines or exposed terminals of electrical apparatus are subject to the minimum safe working distances established in HVEPS–OI–012.
- Construction equipment shall be separated far enough from such lines and apparatus so that equipment failure would not result in the construction equipment approaching energized electrical facilities closer than the established minimum safe work distance.
- All equipment shall be effectively grounded (to ensure proper fault protection) when being moved or operated in close proximity to energized lines or electrical apparatus. Consideration shall be given to grounding the load, particularly if insulated lifting straps are in use. All such operations shall have a dedicated observer (without any other duties) to warn equipment operators of potentially hazardous situations and/or movements.

6.12 Personal Protective Equipment (for additional information on PPE see GSM Chapter 15)

6.12.1 Hard Hats *(29 CFR 1910.135 and ANSI Z89.1)*

All personnel entering high-voltage electric supply stations, power manholes, electrical cable tunnels, electrical cable rooms, or vaults shall wear a Type I, Class E hard hat conforming to 29 CFR 1910.135 and ANSI Z89.1.

6.12.2 Eye Protection *(ANSI Z87.1 and ASTM F 2178)*

Safety glasses, goggles, or face shields shall be worn by an individual in any area or during any work where there is a reasonable probability of eye injury. Eye and face protection shall meet or exceed ANSI Z87.1 Standard "Occupational and Educational Eye and Face Protection Practice" and ASTM F 2178 "Standard Test Method for Determining the Arc Rating and Standard Specification for Eye or Face Protective Products".

6.12.3 Safety Shoes *(ASTM F2412 and F2413)*

All personnel who regularly enter high-voltage electrical supply stations, power manholes, cable tunnels, etc., shall wear safety shoes meeting the requirements of ASTM F2412 and F2413.

6.12.4 Rubber Insulating Gloves *(ASTM D 120 and ASTM F 496)*

Rubber gloves used for protection against electrical shock shall meet the requirements of ASTM D 120, "Standard Specification for Rubber Insulating Gloves" and be tested in accordance with American Society for Testing and Materials (ASTM) F 496, "Standard Specification for Rubber Insulating Gloves in Service Care." In addition, ASTM F 1236, "Standard Guide for Visual Inspection of Electrical Protective Rubber Products" provides suggested methods of pre-use inspections to ensure glove integrity.

All qualified switch persons shall have two pairs of personal rubber insulating gloves, protective leather gloves, and a glove bag. Protective leather gloves shall always be worn over lineman-type rubber gloves and will be in accordance with ASTM F 696, "Standard Specification for Leather Protectors for Rubber Insulating Gloves."

Preferable glove construction shall be in contrasting two-color combinations. The contrast between the thin outer color against the inner color makes inspecting for cuts and tears easier when the glove is inflated or stretched. Whenever the inner rubber color is visible, the pair of gloves shall be discarded.

6.12.5 Hot Sticks *(ANSI/IEEE Standard 516 and* 29 CFR 1910.269(j)*)*

All hot sticks (live-line tools) shall be made of fiberglass and shall meet the requirements of 29 CFR 1910.269(j). Field care, handling, and storage shall be per ANSI/IEEE Standard 516, Section 4. Hot sticks shall be removed from service every 2 years and whenever required under paragraph 29 CFR 1910.269 (j)(2)(ii) for examination, cleaning, repair, and testing.

6.12.6 Protective Clothing *(NFPA 70E)*

Personnel shall wear protective clothing as required by NFPA 70E, Table 130.7(C)(10), when performing energized work, whether or not an Energized Electrical Work Permit (GRC780) is required. Table 130.7(C)(10) lists the requirements for protective clothing and other protective equipment based on Hazard/Risk Category numbers 0 through 4. This clothing and equipment shall be used when working within the Arc Flash Protection Boundary.

Table 130.7(C)(11) lists examples of protective clothing systems and typical characteristics, including the degree of protection, for various clothing. The protective clothing selected for the corresponding Hazard/Risk Category number determined from Table 130.7(C)(9) (including associated notes) and the requirements of 130.7(C)(10) shall have an arc rating of at least the value listed in the last column of Table 130.7(C)(11). Flame Resistant (FR) clothing that has an arc rating based on testing defined by ASTM F 1506, "Standard Performance Specification for Flame Resistant Textile Materials for Wearing Apparel for Use by Electrical Workers Exposed to Momentary Electric Arc and Related Thermal Hazards", and ASTM F 1959, "Standard Test Method for Determining the Arc Thermal Performance Value of Materials for Clothing", adheres to these requirements.

6.13 Equipment Safety Tests and Checks *(ANSI/IEEE or NETA)*

6.13.1 Tests To Be Performed Prior to Initial Energization

a. Initial energization of all new electrical equipment shall be done only in the presence of the appropriate Government representative. Before the initial energization, feeder circuit breakers shall be checked for proper adjustments in accordance with the manufacturer's instructions. (Molded-case circuit breakers without solid-state trip devices are excluded from this requirement.)

b. All protective relays and other such devices shall be tested to be sure that they can operate in the range required. Where possible, tests shall include loading in at the current transformer secondaries to validate the circuitry as well as the device.

c. All wiring shall be checked for conformity to the design and to functional requirements.

d. All motors, cables, and switchgear shall be tested in accordance with industry standards and manufacturer's recommendations, at voltage levels approved by the appropriate Systems Manager for the specific type of equipment. The following industry standards shall apply:

TABLE 6.2.—TESTING STANDARDS

Equipment	Standard[a]
Motors	ANSI/IEEE or ANSI/NETA[b]
Cables	AEIC or ANSI/NETA
Paper-insulated	AEIC or ANSI/NETA
Rubber, ethylene, propylene rubber, cross-linked polyethylene-insulated	ICEA or ANSI/NETA
Switches	ANSI/IEEE or ANSI/NETA
Transformers	ANSI/IEEE or ANSI/NETA

[a]See appropriate Systems Manager to determine preferred standards and methods

[b]InterNational Electrical Testing Association

6.13.2 Circuit-Interrupting Devices

All circuit-interrupting devices shall be rated to interrupt the maximum short-circuit current that can be supplied by the power system at the point of application of the device.

Whenever a proposal is made to add circuit-interrupting devices to the system and whenever large loads are added or major system changes are made, the responsible engineering organization shall make system short-circuit studies to establish the circuit-interrupting duty requirements. All such studies shall be reviewed and approved by the responsible Facilities Division Systems Manager.

After any operation in which a circuit breaker opens under short circuit or fault conditions, the circuit breaker shall be inspected, relay targets reviewed and an assessment made to determine the reason for why the breaker operation occurred. Only after this assessment and the cause for the tripping isolated/removed can the circuit breaker be reclosed and the circuit re-energized. The inspection and assessment shall be reviewed by a qualified operator with support from the responsible FD System Manager.

Since fuses do not have associated relaying (targets) to provide information as to their opening the circuit, unless the reason for the operation occurring is evident (i.e. a known overload situation), only after proper lockout/tagout has occurred, minimum testing (meggar) accomplished and the fault situation been isolated/removed may the fuse be replaced and the circuit restored.

6.13.3 Protective System Checks

Protective relay settings shall be coordinated to provide selective tripping. The appropriate Electrical Systems Manager shall maintain a listing of the required settings and the frequency of periodic testing of all protective relays in use. All HVEPS protective relays shall be checked and calibrated on a triennial basis. Every reasonable effort shall be made to perform an end-to-end test of the relay circuitry in the process of this check, including verification of the integrity of grounds, grounding cables, grounding resistors, and grounding transformers.

6.13.4 High-Voltage Insulation Testing

High-voltage test levels and procedures for all operating equipment shall be verified with the HVEPS Manager to ensure that the test voltage selected and/or procedure used is based on evaluations of the type and condition of insulation, age, damage, equipment history, and desired service, as recommended in ANSI/IEEE 95 (Insulation Testing of Large AC Rotating Machinery with High Direct Voltage) or in NETA MTS (Maintenance Testing Specifications).

High-voltage dielectric testing shall be performed in the presence of the DSP. Isolation, tagging, area securing, and grounding procedures as required shall precede testing. During testing, all safety precautions listed in the respective standard/specification shall be followed.

6.14 Experimental Equipment *(GLM–QS–1700.1)*

6.14.1 Safety Responsibility

Experimental electrical or electromechanical equipment that is under development, and therefore subject to frequent modifications, can present a particular hazard to personnel. The operating and emergency procedures and attendant hazards may change from day to day. The project manager is responsible for the safety of personnel and equipment associated with the development of experimental apparatus. A responsible member of the team shall perform and document periodic assessment of project/equipment hazards using, as a minimum, a Safety Permit Hazard Analysis form, GRC923A, can be completed through the GRC Electronic Safety Permit System.

The frequency of these assessments will be determined by the initial and applicable Area Safety Committee Review and listed as a requirement on the safety permit.

These assessments shall be used to establish correct working procedures, to identify need and use of appropriate PPE, and to establish proper emergency procedures. Particular emphasis shall be placed on de-energization of the equipment.

6.14.2 Experimental, Developmental, or Flight-Level Electrical/Electronic Equipment (NFPA 70E)

Following are additional guidelines for working on or near energized electrical experimental, developmental, or flight-level electrical/electronic equipment:

a. A responsible member of the research and development team such as the Project Engineer shall establish correct working procedures as well as proper precautions, warnings, emergency procedures, and some approved operators list. Safety should be a recurring topic of discussion during project team meetings. Emphasis should be placed on establishing and familiarizing project personnel with emergency procedures to de-energize the equipment. New project personnel shall be apprised of unusual shock hazards associated

with the equipment. All work shall be in accordance with NFPA 70E, Standard for Electrical Safety in the Workplace.

b. As a minimum, guards shall be provided around exposed connections energized above 50 V rms per the NEC.

c. After de-energizing (per GRC Lockout/Tagout Program), a required minimum discharge time should be observed and/or grounding probe(s) should be utilized to discharge circuits prior to physical contact or circuit modifications to ensure that no residual or hazardous voltages remain.

d. Where reasonable and possible, fail safe and/or current limiting circuits should be incorporated in equipment to minimize effects of personnel exposure to hazardous electric shock energy.

e. Temporary wiring utilized shall (1) be rated for the environment and use, (2) be routed in a reasonably neat manner, and (3) not pose unreasonable additional hazards and (4) meet the requirements of the NEC unless justified in writing by the GRC Fire Protection AHJ.

f. Periodic hazard assessment of project/equipment hazards and identification of appropriate PPE shall be conducted using GRC Job Hazard Analysis form GRC239 or equivalent hazard analysis process. Faulty equipment, frayed cords, or faulty grounding conditions shall be repaired (per LVEPS-OI-10) or eliminated.

6.14.3 Experimental Equipment Utilizing High-Voltage Capacitor Banks

Test personnel conducting experiments in which capacitor banks with voltages above 600 V are employed shall have total knowledge of the experiment, the circuit, and the component layout. Safety Permit Requestors shall ensure all personnel tasked to the project are fully trained in the operating and safety procedures to be used at that facility, including procedures to be used in the event of equipment failure. These personnel should be listed on a Qualified Operators List (GRC580) within the GRC Electronic Safety Permit System. General guidance for use of capacitors on power circuits is contained in NEC Article 460 and paragraph 8.8.16. Additional precautions and procedures are as follows:

a. Each high-voltage test area shall be enclosed and protected by using gates and interlocks on the test controls. Since capacitors and related high-voltage component faults are a source of hazardous shrapnel, these components shall be isolated in a manner that precludes personnel injury or facility-related hazards such as fire.

b. High-voltage warning signs shall be displayed in conspicuous locations. Flashing warning lights shall be used to indicate that tests are in progress.

c. Shorting switches and grounding devices that normally discharge the capacitor bank shall be clearly visible to the test operator. These devices shall be fail-safe and shall function to a safe configuration with no electrical power.

d. A voltmeter connected across the capacitor bank shall be clearly visible to the test operator at all times. A redundant voltmeter shall be installed at the capacitor bank.

e. Prior to touching a high-voltage component within the test area, personnel shall determine, by using a grounding wand approved by the safety manager for the particular installation, that the capacitor bank is fully discharged to a building ground.

f. Extreme caution shall be used on capacitor banks that are operated by dc voltages, since a dc capacitor bank will maintain a residual voltage for extended periods.

g. Capacitors that are connected in series/parallel to form a bank shall be treated with great care, and each capacitor terminal in a series/parallel string shall be properly shorted to ground prior to making any changes to a test bank or circuit.

6.15 Training (NASA General Safety Program Requirements NPR 8715.3C)

6.15.1 Initial Training

The GRC shall develop and provide training to ensure that the purpose and function of the Electrical System Safety program are understood by its employees per NPR 8715.3C, Chapter 3, Section 3.6.1(d). The training shall be coordinated by the Human Capital Development Branch, with civil servant employee records maintained in the System for Administrative, Training, and Educational Resources for NASA (SATERN) and contractor records either stored in SATERN or the contractor's own filing system. The training shall include the following:

- ALL EMPLOYEES (on-site civil servant and contractor) shall complete SATERN Course GRC-111-11, ELECTRICAL SAFETY - WHAT EVERYONE SHOULD KNOW. This short video provides a basic explanation on how electricity works, what it can do to the human body and how to use electricity safely. This video shall be viewed as part of new employee orientation.

- Unqualified Employees working in machine shops, equipment rooms, test cells, etc. (Engineers, Tradespersons, and Janitorial Crews that are not trained to work on electrical equipment but are exposed to electrical circuits/equipment/machinery during the performance of their work) shall complete GRC-4R1343, LC ELECTRICAL SAFETY: SHOCK PROOF-UNQUALIFIED. This video shall also be viewed as part of new employee orientation. Note: The video does not qualify an employee. See Section 5.10 of this chapter on how an employee becomes qualified.

- CERTIFIED LOW VOLTAGE SWITCHPERSON/OPERATOR shall complete the following training:
  - SATERN Course GRC-4R1690, GRC LOW VOLTAGE SAFETY FOR CERTIFIED ELECTRICAL OPERATORS/SWITCHPERSONS. This course will provide information from the Glenn Safety Manual (GSM), Chapter 8, Electrical System Safety including the site specific Low Voltage Electrical Power System Operating Instructions (LVEPS-OI's) an overview of GSM Chapter 9, Lockout/Tagout and an introduction to NFPA 70E the Standard for Electrical Safety in the Workplace. These are regulations and procedures that personnel working as a GRC employee performing electrical tasks are required to be knowledgeable of and adhere to. This is an instructor led class with an on-line test to be taken, through SATERN, when the participants are ready. Tests can be scheduled to be taken off-line if personnel do not have access to SATERN.
  - SATERN Course GRC-4R1693, GRC LOW VOLTAGE SAFETY FOR CERTIFIED ELECTRICAL OPERATORS/SWITCHPERSONS EXAM. This is the on-line test for the above listed course. A passing test score (80 percent) shall provide the on-site certification requirement needed for "Qualified Employees" to perform switching and operating low-voltage equipment.
  - An employee must become a "Qualified Operator" before they can become "Certified".
- Employees exposed to shock hazards shall be trained in:
  - Methods of release of victims from contact with exposed energized electrical conductors or circuit parts. SAFE RELEASE OF AN ELECTRICAL SHOCK VICTIM course GRC-111-15 is available through SATERN
  - Methods of first aid and emergency procedures, such as approved methods of resuscitation, if their duties warrant such training. HEARTSAVER/AED TRAINING Course GRC-4R1402 is available through SATERN. Training of employees in approved methods of resuscitation, including cardiopulmonary resuscitation, shall be certified by the employer annually.

6.15.2 Employee Retraining

For all-of-the-above listed training requirements, retraining of employees shall be accomplished at least every 3 years, per NFPA 70E. Retraining shall also be provided for all employees whenever the employer has reason to believe that there are deviations from or inadequacies in the employee's knowledge or use of the requirements set forth in GSM Chapter 8.

Emergency retraining for those personnel required to provide emergency response (such as "The Buddy" performing release of victim or providing CPR or AED assistance) shall be annual.

The employer shall certify that employee training has been accomplished and medical requirements (if specified in the job classification) is being kept up to date. The certification shall contain each employee's name and dates of training.

7.0 RECORDS

Record Name	Maintained by
Energized Electrical Work Permit GRC780	Code QSS
Training Records for Civil Servants	Code CH within SATERN
Training Records for Contractors	Code CH or Onsite Contractor
Facility Change Request (FCR) GRC29	Code FD
Job Hazard Analysis Form GRC239	Org or Contractor conducting task
Safety Permit Requests GRC923A	Code QSS Safety Permit Program
Qualified Operators List GRC580	Code QSS Safety Permit Program

8.0 REFERENCES

Document Number	Document Name
29 CFR 1910 and 1926	Public Law 91–596, Occupational Safety and Health Act (OSHA), 1970
ANSI/IEEE C2	American National Standards Institute. National Electrical Safety Code
ANSI/IEEE 95	Recommended Practice for Insulation Testing of AC Electric Machinery (2300 V and Above) With High Direct Voltage
ANSI/IEEE 516	Guide for Maintenance Methods on Energized Power Lines
ANSI Z87.1	American National Standard Occupational and Educational Personal Eye and Face Protection Devices
ANSI Z89.1	American National Standard for Industrial Head Protection
ASTM D 120	Standard Specification for Rubber Insulating Gloves
ASTM F496	Standard Specification for In-Service Care of Insulating Gloves and Sleeves
ASTM F696	Standard Specification for Leather Protectors for Rubber Insulating Gloves and Mittens
ASTM F 1236	Standard Guide for Visual Inspection of Electrical Protective Rubber Products
ASTM F 1506	Standard Performance Specification for Flame Resistant and Arc Rated Textile Materials for Wearing Apparel for Use by Electrical Workers Exposed to Momentary Electric Arc and Related Thermal Hazards
ASTM F 2178	Standard Test Method for Determining the Arc Rating and Standard Specification for Eye or Face Protective Products

ASTM F 2412	Standard Test Methods for Foot Protection
ASTM F 2413	Standard Specification for Performance Requirements for Protective (Safety) Toe Cap Footwear
ASTM F1959	Standard Test Method for Determining the Arc Rating of Materials for Clothing
ANSI/NETA ATS	STANDARD FOR ACCEPTANCE TESTING SPECIFICATIONS for Electrical Power Equipment and Systems
ANSI/NETA MTS	STANDARD FOR MAINTENANCE TESTING SPECIFICATIONS for Electrical Power Equipment and Systems
ESD TR20.20	Handbook for the Development of an Electrostatic Discharge Control Program for the Protection of Electronic Parts, Assemblies and Equipment
HVEPS–OI–xx	High-voltage Electric Power System Operating Instructions. Various dates
LVEPS–OI–xx	Low-voltage Electrical Power System Operating Instructions. Various dates
GLM–QS–1700.1	NASA Glenn Safety Manual, BMS Document
NPR 8715.3C, Chapter 3.6	NASA General Safety Program Requirements Chapter 3.6
GLP-FB-8810.1	Facility Drawing File Management
NFPA 70	National Electrical Code
NFPA 70E	Standard for Electrical Safety in the Workplace

APPENDIX A. DEFINITIONS AND ACRONYMS

Following are some key definitions related to electrical safety. Many additional related definitions are contained within referenced documents such as the National Electrical Code (NEC) and the National Electrical Safety Code (NESC).

Arc Flash (Flash Hazard).—A dangerous condition associated with the release of energy caused by an electric arc.

Area Clearance Process. — Documented way of communicating a disruption in service. Primarily used to notify Affected Employees when performing lockout/tagout impacts their ability to perform their assigned tasks.

American Society of Testing and Materials (ASTM)

American National Standards Institute (ANSI)

Association of Edison Illuminating Companies (AEIC)

Authority Having Jurisdiction (AHJ) – The organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

Automated External Defibrillator (AED).—this is a portable electronic device that automatically diagnoses the potentially life-threatening cardiac arrhythmias of ventricular defibrillation and ventricular tachycardia in a patient and is able to treat them through defibrillation.

Cardiopulmonary Resuscitation (CPR).—an emergency procedure in which the heart and lungs are made to work by manually compressing the chest overlying the heart and forcing air into the lungs. CPR is used to maintain circulation when the heart stops pumping.

GRC Designated High Voltage Safety Person (DSP)

Electrical Applications Safety Committee (EASC)

Electrically Safe Work Condition.—A state in which the conductor or circuit to be worked on or near has been disconnected from energized parts, locked/tagged in accordance with established standards, tested to ensure absence of voltage, and grounded if deemed necessary.

Electric Supply Equipment.—Equipment that produces, modifies, regulates, controls, or safeguards a supply of electric energy.

Electric Supply Station.—Any building, room, or separate space within which electric supply equipment is located and the interior of which is accessible, as a rule, only to qualified persons. This includes substation, transformer, storage battery and switchgear rooms or enclosures, but does not include facilities such as pad-mounted equipment and installations in manholes and vaults.

Enclosure.—The case or housing of apparatus, or the fence or walls surrounding an installation to prevent personnel from accidentally contacting energized parts or to protect the equipment from physical damage.

Facilities Division (FD)

Fine Print Note (FPN).—Are not requirements and are for information purposes only.

Glenn Safety Manual (GSM)

Glenn Research Center (GRC)

Guarded.—Covered, shielded, fenced, enclosed, or otherwise protected by means of suitable covers, casings, barriers, rails, screens, mats, or platforms to remove the likelihood of approach or contact by persons or objects to a point of danger.

High-voltage electrical power system operating instructions (HVEPS–OI)

International Electrical Testing Association (NETA)

Insulated Cable Engineers Association (ICEA)

Institute of Electrical and Electronics Engineers (IEEE)

Job Hazard Analysis (JHA)

Lockout/Tagout.—Method of controlling hazardous energy sources.

Low-Voltage Electrical Power System Operating Instruction (LVEPS-OI)

Maintenance Testing Specification (MTS)

National Aerospace and Space Administration (NASA)

National Electrical Code (NEC)

National Electric Safety Code (NESC)

National Fire Protection Association (NFPA)

NASA Procedural Requirements (NPR)

Occupational Safety and Health Administration (OSHA)

Personal Protective Equipment (PPE).—Equipment designed to protect employees from serious workplace injuries or illnesses resulting from contact with chemical, radiological, physical, electrical, mechanical, or other workplace hazards.

Potential Transformer (PT).—A potential transformer is a special type of transformer that allows meters to take readings from electrical service connections with higher voltage (potential) than the meter is normally capable of handling without at potential transformer.

Qualified Operator (Switch person).—A person that has (1) Received site-specific knowledge of both the equipment being operated and the system(s) it may impact. (2) Been trained on the maintenance and safe operation of particular equipment including, specific voltages, and the proper PPE. (3) Received instruction on lockout and/or tagout through the GRC Lockout/Tagout Program.

Qualified Person.—One who has skills and knowledge related to the construction and operation of the electrical equipment and installations and has received safety training on the hazards involved. See NFPA 70E, Standard for Electrical Safety in the Workplace, Article 110.6.

Safety and Health Division (SHeD)

Shock Hazard.—A dangerous condition associated with the possible release of energy caused by contact or approach to live parts.

Voltage (of a circuit).—The greatest root-mean-square (effective) difference of potential between any two conductors of the circuit concerned.

Voltage (nominal).—A value assigned to a circuit or system for the purpose of conveniently designating its voltage class (e.g., 208Y/120 V; 2400 V; 34 500 V). The operating voltage of the system may vary above or below this value within a range that permits satisfactory operation of equipment.

Voltage, Low.—Electric system and equipment operating at 600 V nominal or less.

Voltage, High.—Electric system and equipment operating at above 601 V nominal.

APPENDIX B. EXAMPLES OF SIGNS AND LABELS

WARNING
HAZARDOUS AREA

BUILDING: 44

THE ELECTRICAL INSTALLATION IN THIS AREA IS RATED FOR:

CLASS 1, DIVISION 2, GROUP D

IN COMPLIANCE WITH NFPA 70

NO MODIFICATIONS MAY BE MADE TO THIS
AREA WITHOUT WRITTEN APPROVAL FROM
Robert Vanek, 3-2698.

THE GLENN OPERATING ORGANIZATION RESPONSIBLE FOR THIS AREA IS:
Facilities Division, Systems Management and Maintenance Branch - DFI

Sign printed on 2-10-06 To update this sign please contact the Glenn Safety Branch, e-mail: Safety-Office@GRC.NASA.GOV

Figure B.1.—Hazardous Area Warning Sign

Figure B.2.—Supply Station Entry Sign

Figure B.3.—Arc Flash Label

APPENDIX C. Correlation of Current in Amperes and Reaction with the Human Body

TABLE 8.1—FROM NFPA "THE ELECTRICAL SAFETY PROGRAM" (TABLE 7.1)

Reaction of human body to electric current	Current in amperes (small body - large body)
Perception threshold (tingling sensation)	0.0007–0.0010
Slight shock—not painful (no loss of muscle control)	0.0012–0.0018
Shock—painful (no loss of muscle control)	0.0060–0.0090
Severe shock (muscle control loss & difficulty breathing)	0.0150–0.0230
	0.1000–0.1000
Possible ventricular fibrillation (1-sec shock)	0.2000–0.2000
Heart muscle activity ceases	0.5000–0.5000
Tissue and organs burn	1.5000–1.5000

Example: Utilizing Ohm's Law

(Hand contact + internal + foot contact = Total resistance)

500 ohms + 100 ohms + 500 ohms = 1100 ohms

120 volts/1100 ohms = 0.1091 amps

Note: *Some persons who handle electrical equipment mistakenly believe that their tolerance to electric shock is related to their ability to withstand the pain of the shock. Actually, the lethal occurrence is a function of the amount and duration of current passing through the chest. Furthermore, a lethal current may only be marginally higher than one ranked just painful. It is cur-rent, not voltage, that causes physiological damage to humans. As the magnitude of the current increases, statistically the current is more dangerous as a cause of burns than as a cause of heart failure. Although resistance varies with many factors, the accepted value for the internal resistance of the human body is 100 ohms, and 500 ohms is used as a reasonable expectation for contact (touch) resistance. Several factors can impact contact resistance such as coarseness of the skin, area of contact, contact pressure, and degree of wetness of the surface. These factors can lower the overall resistance and allow increased current to flow.*

This amperage, based on the table above, is of sufficient value to cause ventricular fibrillation, which could be fatal. Note that this is based on only 120 V, which we all use on a daily basis. Wet hands or breaks in the skin would decrease the resistance more and increase the current through the body.

APPENDIX D. "WHEN IS THE BUDDY SYSTEM REQUIRED DURING ELECTRICAL APPLICATIONS"

Who's your "Buddy"? Someone working with or perhaps observing the work of another employee, when the task is potentially hazardous. The main benefit of the system is improved safety; to be able to prevent the other from becoming a casualty in a crisis situation where minutes can mean the difference between life and death.

When is a "Buddy" required? When personnel are exposed to an electrical hazard. See electrical hazard definition below.

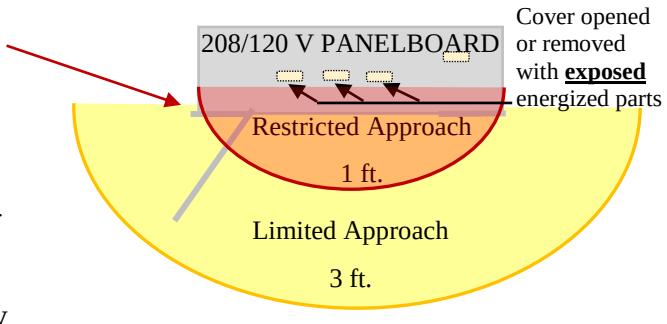
Electrical Hazard. A dangerous condition such that contact or equipment failure can result in electric shock, arc flash burn, thermal burn, or blast.

> **Shock Hazard.** A dangerous condition associated with the possible release of energy caused by contact or approach to energized electrical conductors or circuit parts. A shock hazard is generally considered to exist under normal conditions when a person is exposed to a voltage of 50 volts or greater.
>
> **NFPA 70E Informative Annex K -** General Categories of Electrical Hazards
>
> K.2 Electric Shock.
>
> Approximately 30,000 nonfatal electrical shock accidents occur each year. The National Safety Council estimates that about 1000 fatalities each year are due to electrocution, *more than half* of them while servicing energized systems of *less than 600 volts*. Electrocution is the fourth leading cause of industrial fatalities.

When is a "Buddy" required? Breaking of the restricted approach boundary by reach or tool requires both proper shock PPE and the presence of a "Buddy". Also removal of bolted panelboard covers exposing energized parts shall require the presence of a Buddy. Arc flash PPE may already have been required when the Limited Approach Boundary was crossed.

Restricted Approach Boundary; An approach limit at a distance from exposed energized electrical conductors or circuit parts within which there is an increased likelihood of electric shock for personnel.

Only "qualified" employees may cross this boundary. The Limited Approach Boundary is accessible to unqualified employees **when** escorted by a qualified employee. The figure to the right represents boundary values when exposed to voltages of 151V – 750VAC.



Boundary increases for voltages above 750VAC, see Table 130.4(D)(a) in NFPA 70E

When is a "Buddy" not required? Once an **Electrically Safe Work Condition (ESWC)** is established, shock and arc flash PPE are no longer required nor is the need (electrically) for a "Buddy" required.

Electrically Safe Work Condition (ESWC). A state in which an electrical conductor or circuit part has been disconnected from energized parts, locked/tagged in accordance with established standards, tested to ensure the absence of voltage, and grounded if determined necessary.

Establishing an ESWC is the only work procedure that ensures that an electrical injury cannot occur. Until the ESWC is established (including verification of the loss of potential), an unacceptable risk of injury from exposed energized electrical conductors or circuit parts exists and a Buddy is required.

What Does A "Buddy" Need To Know?

NFPA 70E 110.2(C) Emergency Response Training;

Contact Release. Employees **exposed to shock hazards** shall be trained in methods of **safe** release of victims from contact with exposed energized electrical conductors or circuit parts.

The **"Buddy"** becomes exposed to a shock hazard when trying to free the victim. They also need to be trained **and** provided the proper PPE to perform the release of the electric shock victim safely.

Retraining on the safe release of electrical shock victims, as of the 2015 version of NFPA 70E, shall occur annually.

SATERN Course GRC-111-15

"SAFE RELEASE OF AN ELECTRICAL SHOCK VICTIM" is available on line as a means of providing this training

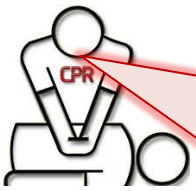
First Aid, Emergency Response and Resuscitation

Employees responsible for responding to medical emergencies shall be trained in

a) First aid and emergency procedures.

b) Cardiopulmonary resuscitation (CPR).

c) In the use of an automated external defibrillator (AED), if an employer's emergency response plan includes the use of this device.



Call 911 (from inside line) or from an outside line or cell phone
At Lewis Field
216-433-8888
At Plum Brook
419-621-3222

NOTE: Emergency Response Retraining shall occur annually.

Questions? Contact the Safety and Health Division (SHeD) 3-3016 or 3-3019